Physiological sensing
For Human Computer Interaction

Leonardo Gizzi
Motivation

• Physiological sensing = probing a living system

• Tons of information (intrinsic coherence)

• We need to know what we are dealing with

• Reduce the distance between human and computer
Why should we use physiological sensing … for HCI?
Why should we use physiological sensing … for HCI?

Physiological transparency
Why should we use physiological sensing
… for HCI?
Why should we use physiological sensing … for HCI?

- **Pros**
  - Intuitive / Trainable
  - Voluntary / Involuntary
  - Applicable with non-cooperative subjects
  - Subject-tailored

- **Cons**
  - Prone to errors:
    - Measurement
    - Misclassification
    - Misinterpretation
  - Computational burden
  - Privacy
What do we need
...for a happy physiological sensing?
Behaviour and Physiological variables

Behaviour to model

System

Physiological variable

Modified from: https://upload.wikimedia.org/wikipedia/commons/d/d8/Organ_Systems_I.jpg

University of Stuttgart
Excitable cells
Anatomy of a neuron

Dendrite

Cell body

Axon

Nucleus

Axon Terminal

Node of Ranvier

Schwann cell

Myelin sheath
Excitable cells

Kyudo = Archer + Bow

Provides trigger

Stores energy

Provides energy

Ready to shoot!

Inagaki Genshiro

... + target
Excitable cells

Kyudo and Neurons

Inagaki Genshiro

![Inagaki Genshiro](https://upload.wikimedia.org/wikipedia/commons/2/29/Professor_Inagaki_Genshiro.jpg)

![Action potential](https://commons.wikimedia.org/wiki/File:Action_potential.svg)

**Aim**

- **Reload**
- **Release**
- **Aim**
- **Action potential**
- **Depolarization**
- **Repolarization**
- **Failed initiations**
- **Stimulus**
- **Shoot**
- **Threshold**
- **Refractory period**
- **Resting state**

Time (ms)

Voltage (mV)
**Excitable cells**

**Resting potential**

- Provides trigger (other neurons*)
- Provides energy
  - ATP (sodium-potassium pump)

Stores energy (The cell membrane)

Resting potential ≠ 0 (faster)

Moving ions = fun!
Excitable cells
Rate-coded

Maintaining potential
(Cheaper and faster)

No news, good news!

Do you see your nose?
Can you feel your clothes?

Now you do.
Excitable cells
“Integrate and fire”

Dindal 2000
Target: The Nervous System

Central Nervous System

Peripheral Nervous System

Sensory System

Motor System

External stimuli

Somatic NS

Autonomic NS

Physiological Sensing

Voluntary

Autonomous

Brain

Spinal cord
Autonomic Nervous System
Autonomic Nervous System

Fight or Flight!
Motor Nervous system (AKA: Neuromuscular system)
From an idea to a movement

Movement Planning (intention)

Descending Command + Sensory integration

Peripheral integration

Muscles activation
Neuromuscular system
From an idea to a movement

Language processing

Audio processing

Video processing
Neuromuscular system
From an idea to a movement

Sensory Cortical Map
(Penfield and Boldfrey 1937)

Sensory Homunculus
(Price-James S. 2016)
Neuromuscular system
From an idea to a movement

Holobar and Farina 2014

“Strong encoding”
Neuromuscular system
From an idea to a movement
Neuromuscular system

From an idea to a movement

Sinkjær 1996

https://en.wikipedia.org/wiki/Patellar_reflex
Neuromuscular system
From an idea to a movement

http://images.slideplayer.com/26/8554656/slides/slide_2.jpg
Neuromuscular system
From an idea to a movement

Moving ions = fun!

http://faculty.pasadena.edu/dkwon/chapt_11/textmostly/slide47.html
Neuromuscular system
From an idea to a movement

Central control strategies:
rate and recruitment

α motoneurons from spinal cord

Contributions of individual motor units

Surface EMG interference signal

Merletti and Parker 2004

Merletti and Parker 2004
Probing the Human Body

- **Electrophysiology**
  - EMG (s)
  - ECG (a)
  - EEG (s)
  - Skin impedance (a)
  - Arc Reflex (s)

- **Movement analysis**
  - Motion capture (s)
  - IMU (s)
  - Actigraphy (s)
  - Pupillary reflex (a)

- **Metabolism**
  - Gas analysis (a)
  - NIRS (a)
  - Temperature (a)
Example: myoelectric prosthesis control

- Human hand: 27DOF
- Robotic hand: 27DOF*
- Myoelectric control: 3DOF
Example: prosthesis control
The task at hand...
Example: prosthesis control
Why is it so complicated?

- EMG detection
- Flexible control
- Multiple solutions

Why is it so complicated?

Example: prosthesis control
Why is it so complicated?
Example: prosthesis control

Mitigation

- EMG detection (bipolar, high density, multimodal)
- Classification algorithms

- Get ‘creative’ – Quality of life first!

Aszmann 2015

Muceli 2015

Example: myoelectric prosthesis control
Put things in perspective: neural plasticity and learning

http://www.goettinger-tageblatt.de/Goettingen/Uebersicht/Alimatou-Bamba-zu-Forschungsuntersuchungen-in-Goettingen

http://www.nagehu.org/content/Projekte.html
Example: myoelectric prosthesis control
Put things in perspective: machine intelligence

Prosthesis awareness
Probing the Human Body

Summary

• There is a lot of measurements that we can use

• We need to keep in mind the user’s needs

• Signal quality is crucial
  - Physiology = ally
  - Noise = enemy
  - Multimodal rocks!

• We must get creative
  - Neural plasticity
  - Machine intelligence
  - Teamwork
Thank you!

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